Research Article

Analysis of Radiographic Outcomes Comparing Foot Orthosis to Extra-osseous Talotarsal Stabilization in the Treatment of Recurrent Talotarsal Joint Dislocation

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Citation: Steber S, Kołodziej Ł. Analysis of Radiographic Outcomes Comparing Foot Orthosis to Extra-osseous Talotarsal Stabilization in the Treatment of Recurrent Talotarsal Joint Dislocation. J Minim Invasive Orthop, 2015, 2(1): e8. doi:10.15383/jmio.8.

Competing interests:The authors have declared that no competing interests exist.

Conflict of interest: None

Abstract: The partial dislocation of the talus on the tarsal mechanism has been recognized as the root cause of multiple foot and lower extremity pathologies. Many conservative and surgical treatments have been utilized to treat this pathologic condition. The purpose of this multi-centered prospective study was to compare weight-bearing radiographic correction achieved in patients with recurrent talotarsal joint dislocation (RTTJD) treated with foot orthoses to that achieved in the same patients through an extra-osseous talotarsal stabilization (EOTTS) procedure. Radiographic data was obtained with no intervention (barefoot), on the orthosis and post-EOTTS from 19 patients (30 feet). Change to the pathologic angles measured for the talarsecond metatarsal (T2M) on the anteroposterior (AP) view and talar declination (TD) angle on the lateral view were analyzed. The reduction in the angles following the use of orthoses was insignificant in both the transverse and sagittal planes. Following the EOTTS procedure, there was a significant change towards accepted normal weight-bearing radiographic angles in the transverse and sagittal planes. In the transverse plane, the EOTTS procedure resulted in an average 58.92% reduction and in the sagittal plane, a 28.32% reduction compared to pre-operative barefoot measurements. By comparison, the change from barefoot measurements to orthosis was 3.20% and 2.20% respectively. The EOTTS procedure did not result in an increase in pathologic angles or cause any angles that were within the normal range pre-operatively to become pathologic. These results support the hypothesis that the EOTTS procedure is more effective in stabilizing RTTJD as compared to orthoses.

Keywords: Ankle joint; Dislocation; Extra-osseous talotarsal stabilization; Hyperpronation; Tarsal bones

Introduction

Thetalotarsal joint (TTJ) plays a vital role inthe normal biomechanical function of the foot and ankle complex, as well as that of the proximal and distal musculoskeletal structures. The TTJ is comprised of the talar articulations on the calcaneus (anterior, middle and posterior facets) and on the navicular. The TTJ and involved bones comprise the talotarsal mechanism (TTM). Under weight-bearing conditions, the TTM acts as a closed kinematic chain with interdependence of the TTJ motions, i.e., motion at one joint influences the other joint(s)(1). A stable TTM leads to a specific amount of motion between these bones to properly distribute the weight-bearing forces. It acts as a torque converter transferring the forces from the leg through the foot and onto the weight-bearing surface below, and also transforming the ground reaction forces (GRF) acts on the foot into transverse plane rotations of the femoral and tibial components (2-5). The stability of the talus on the tarsal mechanism depends mainly on the contour of the articular facets followed by the peri-articular ligamentous support.

Hypermobility of the TTM results in abnormal biomechanics of not only the foot and ankle complex, but also the lower kinematic chain. The diagnosis of reducible/partial talotarsal dislocation (RTTJD) indicates a pathologic condition where there is a partial dislocation of talus on the calcaneus and navicular. This leads to an abnormal distribution of forces within the TTJ complex (6). Forces that should, under normal talotarsal stability, pass through the posterolateral facet of the calcaneus instead, pass anteriomedially (5). Numerous studies have documented the relationship between TTJ instability and biomechanical aberrations such as plantar fasciitis/fasciopathy, navicular drop, progressive posterior tibial tendon dysfunction, tarsal tunnel syndrome, sinus tarsi syndrome, hammertoes, hallux abducto valgus and patellar tracking problems (5-12).

The purpose of this multi-centered prospective study was to determine the radiographic correction achieved in patients diagnosed with RTTJD through use of orthoses as compared to the EOTTS procedure. In this study, it is hypothesized that the osseous alignment achieved after surgical intervention would be significantly greater than that achieved through the use of orthoses. Moreover, the correction achieved with EOTTS would be within the acceptable range of angular measurements for normal feet.

Materials and Methods

This study was reviewed and approved by Quorum Institutional Review Board (Seattle, WA). Diagnosis, enrollment and treatment were performed by four independent foot and ankle specialists from four different facilities,located in Souderton, PA, Cheyenne, WY, Vineland, NJ and Spokane Valley, WA.A total of 19 patients (30 feet) diagnosed with RTTJD participated. These patients were prescribed foot orthoses for a period of time for the purpose of stabilizing the TTJ complex and/or symptom relief. When this form of treatment failed to adequately address the patient's symptoms, they were presented with the surgical options, including EOTTS. To measure the correction achieved by use of the orthoses, if any, the pre-intervention, barefoot weight-bearing radiographs of the patients were compared to weight-bearing radiographs with the placement of the foot on the orthosis. These patients then consented to undergo an EOTTS procedure. It should be noted that no adjunctive hindfoot, midfoot, metatarsal osteotomies or arthrodesis procedures were performed. Post-EOTTS, radiographs were taken when the patient was able to stand with full weight on their foot without any limitation or alteration in standing or walking making sure to eliminate any possibility of internal inflammation or pain that could alter the post-procedure radiographic correction. All of the radiographs were taken with the feet in the normal angle and base of gait in resting stance position.

Patient Selection Procedures

The diagnosis of RTTD was determined through detailed clinical evaluation and confirmed via radiographic analysis.All of the patients included in this study were diagnosed with RTTJD by their foot and ankle physician. Patient ages ranged from 9 - 71 years. Conservative measures such as accommodative footwear, over-the-counter and custom foot orthoses devices, non-steroidal anti-inflammatory and steroidal anti-inflammatory oral medications and steroid injections had failed to alleviate the pain associated with the RTTJD. Patients that had a rigid or semi-rigid non-reducible hindfoot deformity, destructive osteoarthritis, previous hindfoot/midfoot/metatarsal osseous procedures, local active infection, poor bone stock, children 3 years old and younger and vascular-compromised patients were excluded from this study.

Radiographic Evaluation

Radiographic evaluation was based on angular measurements in both the anteroposterior (AP) and lateral views. In the AP view, the talar second metatarsal (T2M) angle was measured. Values greater than 16° are considered pathologic (5). On the lateral radiographs, the talar declination (TD) angle was measured. TD angles greater than 21° are considered pathologic (13, 14). It should also be noted that obliteration of the sinus tarsi, resulting from the partial dislocation of the talus over the calcaneus and navicular, will be evident on pre-operative lateral radiographs. Pre-operative weight-bearing AP and lateral view radiographs of the foot were collected for all the patients, barefoot and with the orthosis in place. Post-EOTTS weight-bearing radiographs were then collected in the same manner with the patient barefoot. The T2M and TD angles were measured using software Surgimap Spine software version 1.1.2.293(Nemaris, Inc., New York, NY). In the AP view, the T2M angle was measured between the longitudinal bisection of the

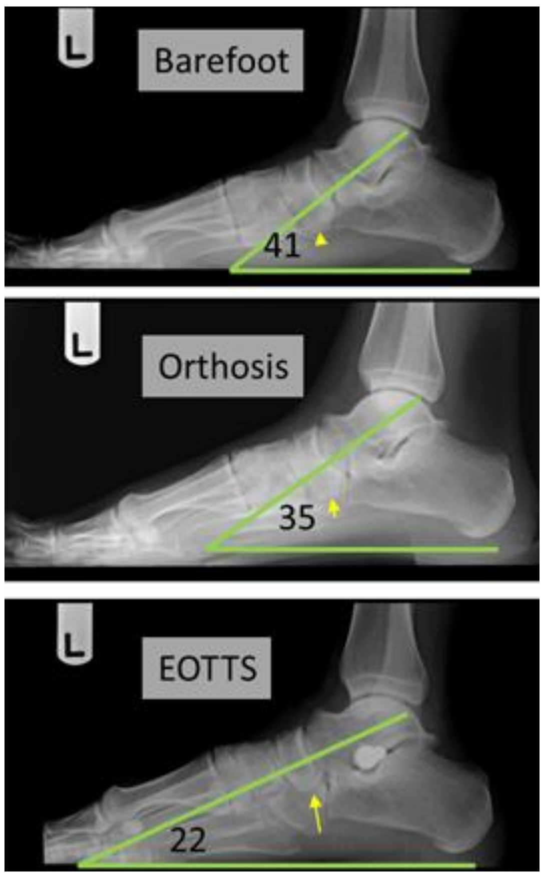

Figure 1. Sample weight-bearing lateral radiographic angle measurement of the talar declination angle (a) barefoot/no intervention (b) with orthosis (c) after extra-osseous talotarsal stabilization (EOTTS).

second metatarsal and the talus (Figure 1) (15). In the lateral view, the TD angle was measured between the longitudinal axis of the talus and the plane of support (Figure 2) (16-18).

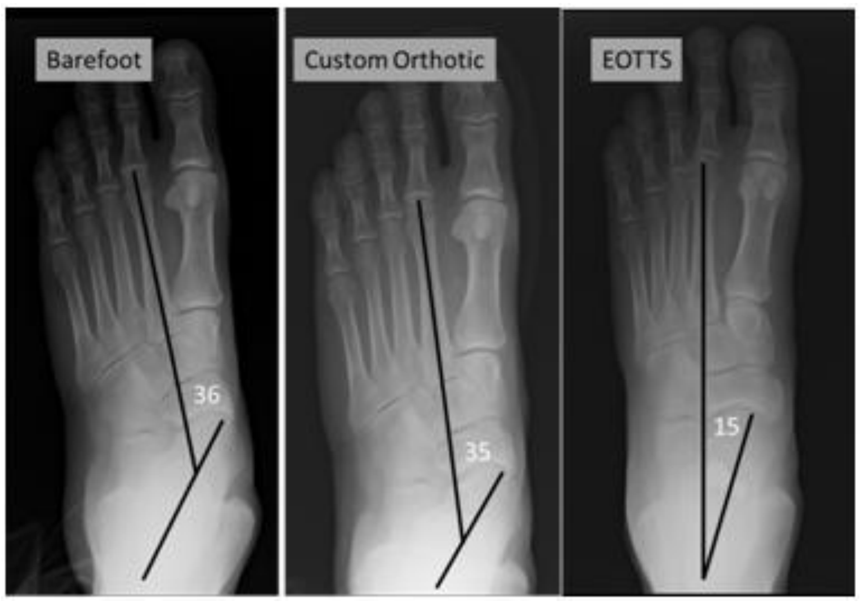

Figure 2. Sample weight-bearing anteroposteriorradiographic angle measurement of the talar second metatarsal angle (a) barefoot/no intervention (b) with orthosis (c) after extra-osseous talotarsal stabilization (EOTTS).

Data Analysis

The mean values of the T2M and TD angles were calculated pre-intervention barefoot, pre-surgical intervention on the orthosis and post-EOTTS procedure. The angular values were compared between groups; barefoot and orthosis, barefoot and post-EOTTS, and orthosis and post-EOTTS.

Statistical Analysis

Statistical analysis was performed for each comparison: barefoot versus orthosis, barefoot versus post-EOTTS, and orthosis versus post-EOTTS. Data were tested for normality using the Kolmogorov-Smirnov test to determine distribution of the sample population. For normally distributed data, a paired t-test was used to determine statistically significant differences between results for pre- and post-operative data points. The Wilcoxon Signed Rank test was used for data that was not normally distributed. Statistical analysis was conducted using SigmaStat Software, version 3.5 (Systat, Chicago, Illinois).

Results

In 19 patients (30 feet) diagnosed with RTTD, the mean T2M and TD values were calculated for the three groups; barefoot versus

Published: 2015-1-15 ★ DOI:10.15383/jmio.8

orthosis, barefoot versus post-EOTTS, and orthosis versus post-EOTTS (Tables 1 and 2, Figures 3 and 4).

Table 1. Comparison of Talar Second Metatarsal Angles for Each Group.

	Barefoot vs. Orthosis (n =28)		Barefoot vs. EOTTS (n = 29)		Orthosis vs. EOTTS (n = 29)	
	Pre-op Barefoot	Pre-op Orthosis	Pre-op Barefoot	Post-op EOTTS	Pre-op Orthosis	Post-op EOTTS
Mean	25.68	24.86	24.93	10.24	25.10	10.17
S.D.	9.46	9.77	10.29	6.17	9.68	5.66
Median	26.50	26.00	26.50	8.00	27.00	8.00
Range	9-42	2-42	9-42	3-21	2-42	2-21
95% C.I. of mean	22.01-29.35	21.07-28.64	22.25-29.33	8.378-12.52	21.42-28.79	8.018-12.33
p value	p =0.2169		**p ≤ 0.001**		**p ≤ 0.001**	
% change	3.20		58.92		59.48	

Note: "n" represents the number of feet. Statistically significant difference is defined by p value ≤ 0.05. Statistically significant p values are marked in bold type.

Table 2. Comparison of Talar Declination Angles for Each Group.

	Barefoot vs. Orthosis (n = 29)		Barefoot vs. EOTTS (n = 29)		Orthosis vs. EOTTS (n = 30)	
	Pre-op Barefoot	Pre-op Orthosis	Pre-op Barefoot	Post-op EOTTS	Pre-op Orthosis	Post-op EOTTS
Mean	29.83	29.17	29.83	21.38	29.07	21.37
S.D.	5.87	5.21	5.87	3.44	5.15	3.38
Median	29.00	29.00	29.00	21.00	29.00	21.00
Range	19-47	17-45	19-47	15-30	17-45	15-30
95% C.I. of mean	27.60-32.06	27.19-31.15	27.60-32.06	20.07-22.69	27.14-30.99	20.11-22.63
p value	p =0.1689		**p ≤ 0.001**		**p ≤ 0.001**	
% change	2.20		28.32		26.49	

Note: "n" represents the number of feet. Statistically significant difference is defined by p value ≤ 0.05. Statistically significant p values are marked in bold type.

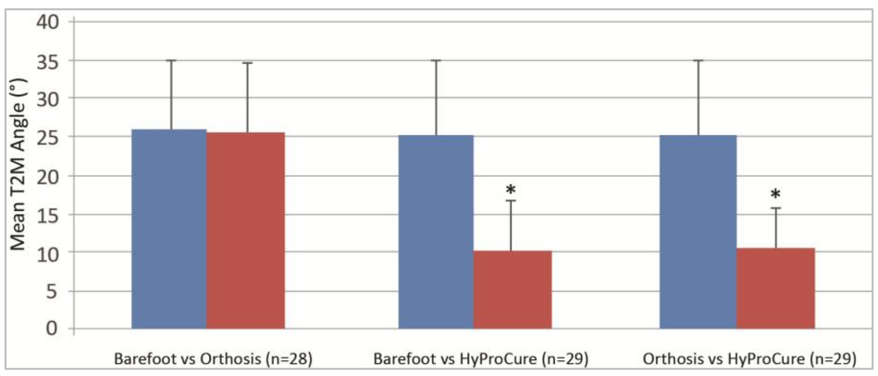

Figure 3. Talar second metatarsalangle comparison. Statistical significance defined by p ≤ 0.001 is indicated by "*".

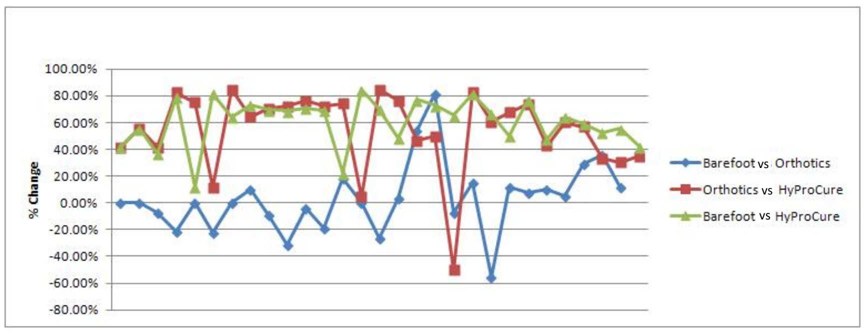

Figure 4. Percent change in talar second metatarsal angles. Negative values indicate an increase.

Table 3. Radiographic Angular Measurements

		T2M Angles			TD Angles		
Patient #	Foot	Barefoot(°)	Orthotics(°)	HyProCure(°)	Barefoot(°)	Orthotics(°)	HyProCure(°)
1	Right	12	12	7	32	37	30
2	Right	9	9	4	19	17	18
3	Right	27	29	17	31	31	26
4	Left	19	23	4	29	29	21
4	Right	Not Available	32	8	Not Available	26	21
5	Left	17	17	15	34	29	25
5	Right	27	33	5	28	29	21
6	Left	42	42	15	41	35	22
6	Right	30	27	8	30	31	20
7	Left	23	25	7	28	28	21
7	Right	16	21	5	24	24	22
8	Left	24	25	7	24	25	19
8	Right	26	31	8	21	22	17
9	Right	27	22	21	31	32	29
10	Left	13	13	2	20	26	15
11	Right	30	38	9	27	30	20
11	Left	31	30	16	32	36	24
12	Right	13	6	3	26	27	18
12	Left	11	2	3	27	27	26
13	Right	29	Not Available	10	27	26	20
13	Left	27	29	5	33	33	24
14	Right	33	28	11	28	32	22
15	Right	20	31	10	32	29	20
15	Left	26	23	6	36	28	22
16	Left	38	35	20	35	31	19
16	Right	39	35	14	28	30	21
17	Left	39	37	16	47	45	18
17	Left	38	27	18	32	26	20
18	Right	36	23	16	29	23	18
19	Left	26	23	15	34	28	22

Talar Second Metatarsal Angle Comparison – Transverse Plane Correction

The sample size for each group varied slightly as the pre-operative barefoot radiograph for 1 patient was unavailable as was the pre-operative radiograph for orthosis for another patient. Looking at the change in the pre-op barefoot to post-EOTTS group, the mean T2M angle value decreased from 24.93° to 10.24°. In the pre-op orthosis to post-EOTTS group, the mean T2M angle value decreased from 25.10 to 10.17. Thus, there was a statistically significant decrease of about 59% for both groups post-EOTTS.

Published: 2015-1-15 ★ DOI:10.15383/jmio.8

The comparison of T2M angles pre-operative barefoot to pre-operative on the orthoses was not statistically significant. As shown in Figure 4, in no cases did the EOTTS procedure increase T2M angles from pre-operative barefoot. In 10 cases, the use of the orthosis increased the T2M angle from pre-operative barefoot.

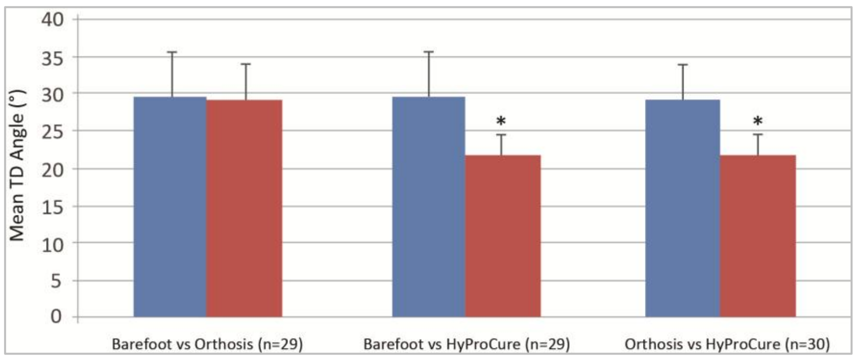

Figure 5. Talar declination angle comparison. Statistical significance defined by p ≤ 0.001 is indicated by "*".

Talar Declination Angle Comparison–Sagittal Plane Correction

The sample size for each group varied slightly as the pre-operative barefoot radiograph for 1 patient was unavailable. Between the pre-op barefoot and post-EOTTS group, the mean TD angle value decreased from 29.83° to 21.38° (Figure 5). For the pre-op orthosis to post-EOTTS group, the mean TD angle value decreased from 29.07 to 21.37. Thus, there was a statistically significant decrease of over 26% for both groups post-EOTTS. The comparison of TD angles pre-operative barefoot to pre-operative on the orthoses was not statistically significant. As shown in (Figure 6), in no cases did the EOTTS procedure increase TD angles from pre-operative barefoot. In 12 cases, the use of the orthosis increased the TD angle from pre-operative barefoot.

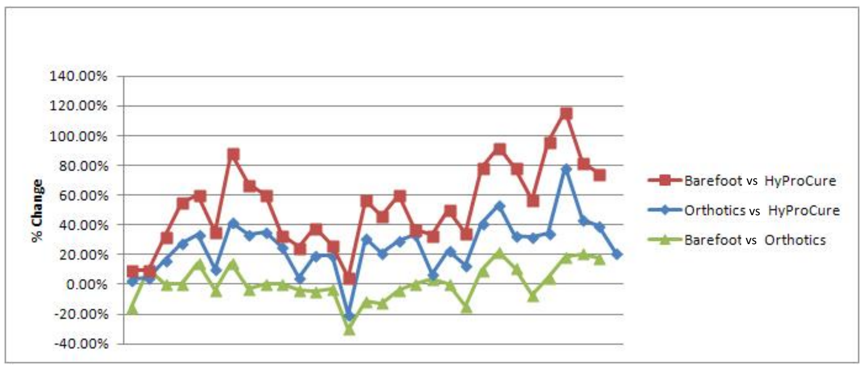

Figure 6. Percent change in talar declination angles. Negative values indicate an increase.

Discussion

Hindfoot instability (RTTJD) leads to an unlocking of the TTM, which in turn is responsible for excessive pronatory moments during static and dynamic weight-bearing activities. This pathologic deformity is characterized by the presence of medial, and/or anterior, and/or plantarflexion displacement of the talus, excessive calcaneal eversion and abduction of the forefoot on rearfoot (19). While standing and with each step taken, there is excessive strain acting on the soft tissues supporting the medial column of the foot, including the spring ligament, medial band of the plantar fascia, posterior tibial tendon, and talocalcaneal ligaments. The Achilles tendon as well as the adjacent osseous structures will also be adversely affected. The recurrent partial dislocation of the talus on the tarsal bones, if not treated in initial stages, leads to various pathologies adversely affecting the lower extremities (9, 20, 21).

A diagnosis of RTTJD depends largely on evaluation of the osseous alignment and position of specific foot structures. Radiographic measurement is one of the most commonly used objective standards in the diagnosis of the osseous deformities. The radiographic views that most correctly identify mal-alignment disorders include the AP/dorsoplantar and lateral views (15). AP radiographs show alignment in the transverse plane and lateral radiographs evaluate thesagittal plane. The TD angle, talo-first metatarsal angle (T1M) and T2M angle have been commonly used to diagnose the correct osseous alignment between the forefoot and hindfoot (5, 15, 22-25). In this study, T2M and TD angles were considered to determine the presence of RTTJD. T2M values for the normal population have been reported as 16.2 ° ± 7.3 °in the bipedal stance position (16) and 18.41 ° ± 6.58 ° in resting stance (15). For a normal foot, the TD angle has been reported as 16.8 °to 37 °; 21 ° and 14 ° to 36 ° (16-18). It has also been stated that the normal TD angle is less than 21 ° (13, 14). For the purposes of this study, weight-bearing T2M angles above 16 ° (5) and TD angles above 21 ° were considered pathologic and used to confirm the presence of RTTJD.

RTTJD is often initially treated by conservative measures, which include a wide variety of corrective orthopedic shoes and over-the-

Published: 2015-1-15 ★ DOI:10.15383/jmio.8

counter and custom-made orthoses and braces (26). Orthoses are mechanical devices placed into a shoe and act on the bottom of the foot. Orthoses are designed to attempt to correct and maintain the foot near optimum position, in order to improve the mechanics of the foot during walking and thus encourage the normal development of the foot (27). One way that orthoses are designed to work is by attempting to limit excessive pronation of the subtalar joint by inverting the subtalar joint to its neutral position throughout the stance phase of gait. By placing the foot in neutral or inverted position, orthoses increase the supination moment opposingthe pronatory ground reaction forces. Thus, the foot is assumed to be realigned with the weight-bearing surface (supporting surface) with orthoses intervention. Orthoses are designed to work by altering the weight-bearing surface, with the medial longitudinal arch elevated and supported (28). There is often a temporary relief of symptoms and improvement in function while orthoses are utilized. The use of orthoses is believed to reduce the excessive strain placed on the supporting soft tissue structures, thus alleviating the symptoms associated with the excessive pronation of the feet. There are several studies that indicate that the use of orthoses help soften ground reactive forces and provide support to the feet (29-32). However, these conservative measures depend greatly on patient compliance and proper shoe gear. It has not been established that use of these orthoses results in correction or improvement in function when they are not in use. Moreover, to the author's knowledge, no study has shown that these external methods provide osseous realignment to within accepted normal values. Also, patients unresponsive to orthoses may continue to experience the excessive strain applied to the soft tissues. Eventually, this can lead to progressive deformities of the foot that may require complex treatment interventions. Studies have been performed to understand the effect of orthoses on the strain to supporting soft tissues in the case of pronated feet (33, 34). However, it is essential to conduct further research on the long-term evaluation of orthoses with the focus on the osseous correction achieved following the permanent removal of the inserts.

In this study, it was seen that the use of orthoses did not have any significant impact on realigning the pathologic angles used to determine the presence of RTTD in patients. The mean radiographic T2M and TD angles changed minimally after the use of orthoses (Table 3). This indicates that talotarsal instability remained essentially the same with or without orthoses. Another key finding was that orthoses could even increase the angular deformity in some patients.

When conservative methods fail, surgical intervention is considered. Traditional surgical options include reconstructive osteotomies, with or without bone grafting, as well as arthrodeses of the joint(s). With these procedures, many issues have been reported, such as degenerative changesof the adjacent articular segments due to the limitation of TTJ motion (9, 10, 35-39). Attempts to avoid these types of complications lead to the development of subtalararthroereisis devices (9, 20, 40-42). Also referred to as Type I EOTTS devices (43), these devices are placed in the sinus tarsi and intend to improve the biomechanics of the foot by blocking the excessive motion of the talus (44-47). Many clinical and biomechanical studies have evaluated the performance of these devices in stabilizing the subtalar joint complex (44, 48-51). While some favorable outcomes have been reported, many of these Type I devices show very high rates of removal (20,44,45,52,53).

The HyProCure® (GraMedica, Inc., Macomb, MI) stent is a Type II non-arthroereisis EOTTS device. A Type II device differs from a Type I arthroereisis device in regard to implant design, the specific manner in which stabilization occurs, and where the device is anchored into the soft tissues within the tarsal sinus. An important feature of a Type II device is the longitudinal *in situ* placement aligned with the normal anatomical orientation of the sinus tarsi. This type of device functions with the natural mechanics of the TTJ, in contrast to the blocking/limiting Type I arthroereisis devices. The transfer of forces from the body above are normalized and allowed to pass in an oblique fashion, i.e. from posterolateral to anteromedial, through thesubtalarcomplex, with a Type II EOTTS device, which restores the normal biomechanics of the TTM (5). This Type II device was designed to improve outcomes and to have a reduced removal rate. HyProCure® has been effective in treating talotarsal instability with a significant reduction in removal rate when compared to Type I arthroereisis devices (54). The goal of EOTTS with a Type II device is to restore the normal subtalar triplane motion by providing stabilization at the cruciate pivot point of talar motion. Many published reports have shown the benefits of the EOTTS procedure such as uniform redistribution of the axial loads on the subtalar facet joints preventing talar displacement on the calcaneus and stabilization of the lowering of the medial longitudinal arch, eventually correcting hyperpronation (5, 55). It has been reported that the EOTTS procedure with this type of device offers complete stabilization of the TTJ complex and restores the normal range of hindfoot motion (54). Stabilization of the TTM would alleviate the pain caused by compression of the posterior tibial nerve in the tarsal tunnel owing to hyperpronation (56).The transfer of forces from the talus effectively passes through the articular facets as they should instead of where they should not. A clinical study performed by Graham et al., showed that HyProCure® was successful in producing positive patient outcomes in 83 patients with overall removal rate of ~ 6% (54).

The results of this study showed that the EOTTS procedure produced a greater and positive change in the radiographic angles as compared to the pre-operative values. In the transverse plane, the mean T2M angle following the EOTTS procedure was reduced to 10.24 °, which is well within the range of the values reported for the normal foot (15, 16). The T2M angle determines the alignment of the hindfoot proximally and the forefoot distally in the transverse plane. A balanced, stable foot would have a low angular measurement, whereas an unbalanced, unstable foot would have a higher than normal angle indicating a medial transverse plane deformity of the hindfoot with respect to the forefoot. A higher than normal value would result from adduction of the talus and abduction of the forefoot with respect to the stable second metatarsal (15). In the sagittal plane, the mean TD angle after the EOTTS procedure was 21.38 ° which is similar to the value reported for the normal foot (13,14,16-18). The TD angle is a positional angle that measures the direction of the talus with respect to the weight-bearing surface. With RTTJD, the talus plantarflexes, thus increasing the TD angle. Hence, the fact that T2M and TD angles were reduced significantly and were similar to the values for the normal foot indicates that EOTTS did result in positive correction of RTTJD.

In a retrospective radiographic analysis of 70 patients (95 feet) who were diagnosed with RTTJD in at least one plane and underwent EOTTS as a stand-alone procedure, it was shown that HyProCure® was effective in normalizing both T2M and TD angles (57). The mean T2M angle pre-op of 24.8 °was reduced by 77% to 5.8 °, while the mean TD angle pre-op of 25.1 °was reduced by 23% to 19.4 °. By comparison, in the present study the mean T2M angle pre-op of 24.93 °was reduced by 59% to 10.24 °, while the mean TD angle pre-op of 29.83 °was reduced by 28% to 21.38 °. These values are similar, more so when the sample sizes and standard deviations are taken into account. Moreover, as in this present study, no angles that were within normal values pre-operatively were made pathologic by the intervention.

There are several studies regardingradiographic assessment, functional outcomes, and kinematic and kinetic data on orthoses intervention reported in the literature (33, 34, 58-62). Literature review acknowledgesthat certain foot orthoses significantly reduce the rearfootpronatory motion, with a decrease in resultant internal tibial rotation as a consequence (63, 64). Zammit et al. reported positive clinical outcomes on orthotics showing significant improvement in pain and function while it showed that orthoses treatment had a small, but significant effect (4% - 8%) on rear foot motion. There were no significant correlations between rearfoot motion with and without foot orthoses and patient outcome scores (33). A biomechanical study on cadavers found that the“UCBL” (University of California Biomechanics Laboratory) and two other “custom-molded” orthoses reduced strain in plantar fascia while the “functional foot orthosis” did not reduce strain. In spiteof the mixed results on kinematic and kinetic studies on foot orthoses, some studies show they result in positive clinical outcomes (33, 34). It has also been reported that use of the UCBL shoe insert decreased pain and improved gait in children with no lasting structural changes (58). In a study conducted by Bleck and Berzins, the use of a UCBL and Helfet foot orthoses in children up to 3 years of age improved their arch in 79% of cases and led to the development of a normal arched foot in 32% (59). However, there was no note on the improved foot position after the removal of the orthotic insert. Bordelon stated that a UCBL produced a 5 ° correction per year in the lateral talometatarsal angle in children (60). His study considered only one parameter in the sagittal plane without considering the correction in the other planes. Some studies also showed that even the long-term use of orthotics may not result in any significant permanent change (61, 62).

Penneau, et al., performed a radiographic comparison of a bare foot with four different orthoses – a Thomas heel, an over-the-counter insert and two specially molded plastic foot orthoses (65). They found that there was not a significant change radiographically by the use of any of the appliances. A more recent study was conducted by Landsman, et al., examining several parameters to determine the efficacy of over-the-counter foot orthoses. They compared radiographic changes with and without arch supports in 41 patients. They claimed statistical significance with a p value ≤ 0.05 (66).

An additionaldrawbackof orthoses are that they can be expensive, individually and over time. These devices require periodic replacement which can become quite costly. Therefore, patients may opt for an over-the-counter device that may provide even less stability than a custom-fit orthosis. As previously mentioned, patient compliance can be a serious limitation to the effectiveness of orthoses.

There are risks associated with the EOTTS procedure, including post-procedure infection (less than 1% risk), under/over-correction and the need for device replacement, possibility for intolerance to the device/correction achieved and the need for device removal, as well as other general risks associated with any surgical procedure (54). To date, there have been no reports of talar or calcaneal fracture, osteomyelitis or need for a below-knee amputation as a result of the EOTTS procedure with a Type II device (GraMedica- after 10 years of clinical use with greater than 36,000 procedures performed). When compared with traditional talotarsal stabilization surgical procedures there are far fewer surgical risks. The procedure is reversible, unlike traditional reconstructive procedures that cannot be undone. As the use of an external fitted/molded arch support does not show radiographic correction of talotarsal dislocation, it should be considered a sub-therapeutic treatment modality and therefore has the associated risk of continued strain and progression of the associated secondary pathologic conditions.

A limitation of this study was that it was strictly a radiographic comparison and there were no functional or symptom-relief measurement tools utilized to establish an associated decrease in symptoms in patients with RTTJD. However, a recent multi-centered prospective study on subjective outcomes using the HyProCure stent reported 1 year post-operative improvements in Maryland Foot Scores of a 37% reduction in foot pain, 14.4% improvement in foot functional activities and 29.5% improvement in foot appearance (67). Further investigation into symptom relief comparing orthoses with EOTTS would be beneficial to expand the evidence base regarding the efficacy of either treatment modality. A further limitation was that RTTJD is a triplanar deformity that can present with planar dominance. In this study, 1 foot showed a transverse plane dominance and four additional feet a sagittal plane dominance. The pre-intervention normal angular measurements for these patients in the other plane may have very slightly skewed the mean correction achieved.

Conclusion

In summary, it can be stated that orthoses alone cannot be considered as an effective treatment to reduce or eliminate RTTJD. In the present study, the EOTTS procedure not only corrected or "normalized" the radiographic angle values significantly but also resulted in values similar to the ideal foot alignment. Hence, this study establishes that EOTTS with HyProCure® can be considered as an effective treatment for correcting RTTJD and ensuring improved biomechanics.

Acknowledgements

The authors would like to acknowledge Philip Bresnahan, DPM, Indian Valley Podiatry Associates, PC, Souderton, PA; Michael More, DPM, Cheyenne, WY; and Paul C. Jones, DPM, InStep

Foot and Ankle, Spokane Valley, WA, for their contributions to this study in enrolling and treating patients.

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